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# ADP010729

TITLE: M219 Cavity Case

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# 20. M219 CAVITY CASE

M J de C Henshaw
British Aerospace (Operations) Ltd.,
Military Aircraft and Aerostructures
Skillings Lane, Brough,
East Riding of Yorkshire,
HU 15 1 EQ
U.K.

## INTRODUCTION

The data contained in this set consists of pressure time histories measured on the ceiling of an empty rectangular cavity, and were measured as part of a joint BAe./DERA programme at the ARA wind tunnel at Bedford during November 1991. The overall programme consisted of several configurations, with bodies positioned at various proximities to the cavity, but the data presented here only considers the empty cavity, configured for both shallow and deep cases. Data were measured using Kulite transducers along the centreline of the rig, (which did not coincide with the centreline of the cavity itself), and, in an alternative configuration, on the centreline of the cavity. Measurements taken off the cavity centreline, but not included here, indicated that 3D effects were not significant.

## DEFINITIONS

| | |
|---|---|
| d | Depth of Cavity |
| L | Length of Cavity (20 in.) |
| M | Mach Number |
| P | Pressure (KPa) |
| X, Y, Z | Co-ordinate directions: X is in direction of the flow, Y is span-wise and Z the vertical directions. |

Note that all lengths are given in feet or inches except for boundary layer and transition lengths which are given in mm.

## FORMULARY

### 1 GENERAL DESCRIPTION OF MODEL

| | |
|---|---|
| 1.1 Designation | Model M219 (referred to as 'generic cavity rig') |
| 1.2 Type | Empty Cavity (shallow and deep configurations). |
| 1.3 Derivation | DERA model manufactured at ARA |
| 1.4 Additional remarks | The data are for 3D cavity. However, further data is available which suggests that there is no variation across the inner 50% of cavity width. |
| 1.5 References | 1,2 |

### 2 MODEL GEOMETRY

| | |
|---|---|
| 2.1 Plan-form | Rectangular cavity 20 in. X 4 in. (length X width). Two depths: 2 in. and 4 in. |
| 2.2 Rig geometry | Flat surface model with inset cavity (see fig 1) |
| 2.3 Cavity position in rig | Cavity offset by 1 in. from flat surface centreline (see fig 1). Cavity leading edge 31 in. aft of flat plate leading edge. |
| 2.4 Additional remarks | Full geometry in attached figures. |
| 2.5 References | 1,2 |

### 3 WIND TUNNEL

| | |
|---|---|
| 3.1 Designation | ARA TWT (Transonic Wind Tunnel) |
| 3.2 Type of tunnel | Continuous flow |
| 3.3 Test section dimensions | 9 X 8 (ft.) |

| | |
|---|---|
| 3.4 Type of roof and floor | Ventilated |
| 3.5 Type of side walls | Ventilated |
| 3.6 Ventilation geometry | Perforated steel plate, 22% open area |
| 3.7 Thickness of side wall boundary layer | Typically 13 mm at model centre-of-rotation station, (empty tunnel with centreline probe). |
| 3.8 Thickness of boundary layers at roof and floor | Typically 13 mm at model centre-of-rotation station, (empty tunnel with centreline probe). |
| 3.9 Method of measuring Mach number | Settling chamber and working section static pressures with calibrated corrections. |
| 3.10 Flow angularity | <0.2° |
| 3.11 Uniformity of Mach number over test section | <±0.0005, (low subsonic, fan only), to <±0.01, (high supersonic, nozzle setting plus plenum suction). |
| 3.12 Sources and levels of noise in empty tunnel | Noise: Broadband rms. $C_P$ < 0.5% across Mach range. Turbulence, (subsonic): u′/U<0.1%, v′/U<0.2% |
| 3.13 Tunnel resonance's | Fan blade passing frequency and harmonics. |
| 3.14 Additional remarks | None |
| 3.15 References on tunnel | 3, 4 |

## 4 MODEL MOTION

| | |
|---|---|
| 4.1 General description | No motion.<br>On-line monitoring of accelerometers indicated no significant model motion.<br>Output from datum pressure transducers, positioned on the flat plate (K1 and K2, see table 1), is available, although not included in this report. This indicated that there were no significant model or tunnel contributions to the unsteady cavity data. |
| 4.2 Angle of attack | zero |

## 5 TEST CONDITIONS

| | |
|---|---|
| 5.1 Model plan-form area/tunnel area | 11.81% |
| 5.2 Model span/tunnel width | 15.74%, (17in/9ft) |
| 5.3 Blockage | 1.16% (119.91 $in^2$) |
| 5.4 Position of model in tunnel | Rig support sting centreline 6in above tunnel centreline at zero incidence. |
| 5.5 Range of Mach numbers | 0.6, 0.85, 1.35 |
| 5.6 Range of tunnel total pressure | 1.0032 to1.0121 bar |
| 5.7 Range of tunnel total temperature | 302.32 to 311.35 deg. K |
| 5.8 Range of model steady, or mean incidence | Zero incidence only. |
| 5.9 Definition of model incidence | N/A |
| 5.10 Position and type of transition trip | 40 mm aft of leading edge of flat plate. Stream-wise width of strip 4 mm. Sparsely distributed ballotini 0.13 to 0.15 mm diameter. |
| 5.11 Flow instabilities during tests | None |
| 5.12 Changes to mean shape of model due to steady aerodynamic load | Not measured, very stiff model |
| 5.13 Additional remarks | None |
| 5.14 References | 1,2 |

## 6 MEASUREMENTS AND OBSERVATIONS

| | |
|---|---|
| 6.1 Steady pressures for the mean conditions | No |
| 6.2 Steady pressures for small changes from the mean conditions | No |
| 6.3 Quasi-steady pressures | Yes (for all conditions, but data not included in this report). |
| 6.4 Unsteady pressures | Yes |
| 6.5 Steady section forces for the mean conditions by integration of pressures | No |
| 6.6 Steady section forces for small changes from the mean conditions by integration | No |
| 6.7 Quasi-steady section forces by integration | No |
| 6.8 Unsteady section forces by integration | No |
| 6.9 Measurement of actual motion at points on model | No |
| 6.10 Observation of measurement of boundary-layer properties | No |
| 6.11 Visualisation of surface flow | No |
| 6.12 Visualisation of shock wave movements | No |
| 6.13 Additional remarks | None |

## 7 INSTRUMENTATION

7.1 Steady/Quasi steady pressures

| | |
|---|---|
| 7.1.1 Position of orifices span-wise and chord-wise | Front plate, rear plate, cavity ceiling, cavity sidewalls, cavity front wall. For distribution see attached figures and table 2. |
| 7.1.2 Type of measuring system | Pressure orifices in model surfaces. Pressure measurement by PSI electronic scanning modules. |

7.2 Unsteady pressures

| | |
|---|---|
| 7.2.1 Position of orifices span-wise and chord-wise | 2 on flat plate ahead of cavity, 2 on front wall of cavity, 10 positioned along ceiling of cavity either on its centreline, (shallow cavity), or 1 inch offset, (deep cavity; note this <u>is</u> the centreline of the rig), and 1 on flat plate aft of cavity. (See figure 1 and table 2) |
| 7.2.2 Diameter of orifices | 0.09in diameter transducers behind 0.063in diameter orifices. |
| 7.2.3 Type of measuring system | High speed digital data acquisition system. Data sampled at 6000 Hz |
| 7.2.4 Type of transducers | Kulite miniature high response XCQ 25PSI differential. |
| 7.2.5 Principle and accuracy of calibration | Calibrated in situ by application of range of steady pressures |

7.3 Model motion

| | |
|---|---|
| 7.3.1 Method of measuring motion reference co-ordinate | N/A |
| 7.3.2 Method of determining spatial mode of motion | N/A |
| 7.3.3 Accuracy of measured motions | N/A |

| | |
|---|---|
| 7.4 Processing of unsteady measurements | |
| 7.4.1 Method of acquiring and processing measurements | High speed digital data acquisition system. Data sampled at 6000 Hz |
| 7.4.2 Type of analysis | Spectral analysis using FFT to obtain power spectral density, rms. amplitude versus frequency and rms. total sound pressure level. Block size 2048 and summation of moving averages. |
| 7.4.3 Unsteady pressure quantities obtained and accuracies achieved | Time history data. Spectral data |
| 7.4.4 Method of integration to obtain forces | N/A |
| 7.5 Additional remarks | None |
| 7.6 References on techniques | Standard "Text Book" techniques have been used. |

## 8 DATA PRESENTATION

| | |
|---|---|
| 8.1 Test cases for which data could be made available | M=0.4, 0.80, 0.98, 1.10 and 1.19. |
| 8.2 Test cases for which data are included in this document | Two configurations (shallow and deep) each at M=0.6, 0.85, 1.35 |
| 8.3 Steady pressures | N/A |
| 8.4 Quasi-steady or steady perturbation pressures | No |
| 8.5 Unsteady pressures | Pressure time history for each pressure tap on cavity ceiling.<br>RMS pressure for each pressure tap on cavity ceiling. |
| 8.6 Steady forces or moments | N/A |
| 8.7 Quasi-steady or steady perturbation forces | N/A |
| 8.8 Unsteady forces and moments | N/A |
| 8.9 Other forms in which data could be made available | Spectral data in rms. amplitude versus frequency form or power spectral density. It is recommended that the reader carry out signal analysis of the experimental data with the same tools that will be used to analyse the CFD data. |
| 8.10 References giving other presentation of data | The data for empty cavity geometries has not been discussed in the open literature. Other reports on related work with non-empty cavities may be made available through application to DERA. |

## 9 COMMENTS ON DATA

| | |
|---|---|
| 9.1 Accuracy | |
| 9.1.1 Mach number | ±0.001 |
| 9.1.2 Steady incidence | ±0.01deg |
| 9.1.3 Steady pressure coefficients | Basic accuracy of system in measuring a steady pressure coefficient at total pressures around atmospheric has been shown to be ±0.5%. However, for the current data steady or quasi-steady pressure coefficients are essentially a time average of a varying pressure and will be less accurate. Quasi-steady pressure coefficients measured at different times have been shown to be repeatable to within ±3%. |
| 9.1.4 Steady pressure derivatives | N/A |
| 9.1.5 Unsteady pressure coefficients | Combined non-linearity and hysteresis of Kulite transducers 0.1% of full-scale output; refer to DERA calibration of entire measurement chain. |
| 9.2 Sensitivity to small changes of parameter | The only parameter varied was Mach number; changes other than those listed were not investigated. |

| | |
|---|---|
| 9.3 Non-linearities | N/A |
| 9.4 Influence of tunnel total pressure | Tunnel total pressure remained nominally constant at 1 bar. |
| 9.5 Effects on data of uncertainty, or variation, in mode of model motion | N/A |
| 9.6 Wall interference corrections | Corrections have been made to Mach number for tunnel blockage due to presence of the model and support system. |
| 9.7 Other relevant tests on same model | Other tests have been made on the same model with stores mounted within the cavity. |
| 9.8 Relevant tests on other models of nominally the same shape | N/A |
| 9.9 Any remarks relevant to comparison between experiment and theory | Methods, under development, for the computation of cavity flow fields gave reasonable agreement between experiment and theory for time averaged or quasi-steady pressures. Early computations of rms. unsteady pressure levels using 2-D methods significantly over-predicted levels in comparison with the measured values. |
| 9.10 Additional remarks | None. |
| 9.11 References on discussion of data | The data for empty cavity geometries has not been discussed in open literature. Other reports on related work with non-empty cavities may be made available through application to DERA. |

## 10 PERSONAL CONTACT FOR FURTHER INFORMATION

J A Ross, HWA, Bld 37, DERA Bedford, MK41 6AE

## 11 LIST OF REFERENCES


1. Aircraft Research Association Ltd., Model Test Note M219/6 "Details of tests in the ARA 2.74m x 2.44m transonic wind tunnel measuring the release disturbance of weapons carried in cavities. " Feb 1993.

2. Aircraft Research Association Ltd. Model Test Note M157/5 "Feasibility study for the measurement of release disturbance of weapons carried in cavities. April 1989.

3. Green J. E., McHugh C.A., Baxendale A.J. and Stanniland D. R., 'The use of a deep honeycomb to achieve high flow quality in the ARA 9' x 8' Transonic Wind Tunnel', presented at 18th Congress of ICAS, Beijing, September 1992.

4. Stanniland D. R., McHugh C.A. and Green J.E., 'Improvement of the flow quality in the ARA Transonic Tunnel by means of a long cell honeycomb', paper 54, RAeS conference on "Wind Tunnels and Wind Tunnel Test Techniques", Southampton, 1992.

# EXPERIMENTAL ARRANGEMENT

The test rig dimensions are given in figure 1, the spoiler was not in place for the tests reported herein and is noted for information only. The location of the kulite transducers for which data is recorded in this database are shown in table 1 and illustrated in Figure 2. for the deep cavity. The cavity centreline is displaced by 1" relative to the rig centreline (see figure 1). For the deep (4") cavity the kulites are positioned on the rig centreline (Y=0), which is 1" to port of cavity centreline[1]. For the shallow (2") cavity the kulites are positioned at Y=1.0 (equivalent to the cavity centreline).

There were also 28 static pressure measurement transducers ahead of the cavity (on the rig centreline) and 14 aft of the cavity. Static measurement locations inside the cavity are noted in table 2.

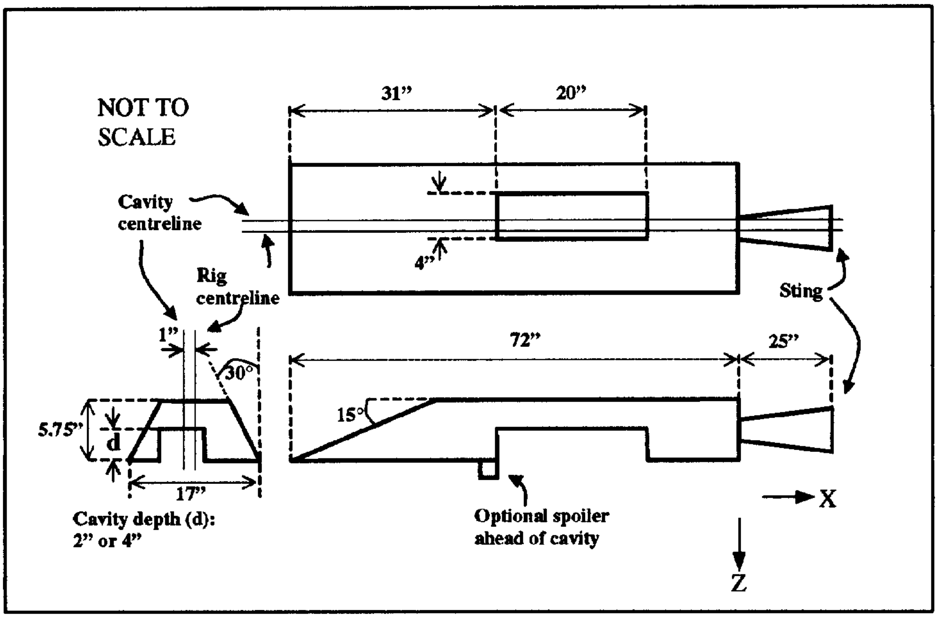


**Figure 1: Test Rig and Dimensions**

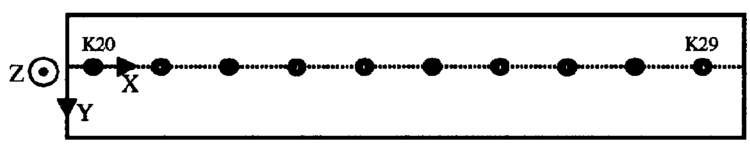


**Figure 2: Position of Kulite Transducers on Cavity Ceiling (deep cavity)**

[1] Cavity is on the rig underside.

## DATA LAYOUT

The data is stored in six files (one for each flow condition), and consists of ten columns corresponding to the ten ceiling transducers in the order K20 to K29 (figure 2). Each column contains the pressure time history in KPa, with each row written in the FORTRAN format 10F14.6.

The time step for the data is implicit in the sampling rate per channel, i.e. a time step of $1/6000$ seconds.

Data files are located in the tree shown in figure 3.

Plots and values of the rms. pressure are included in table 3 (see figures 4 and 5) for the purpose of checking data quality. The values are derived including power up to 3000Hz, using the following parameters:

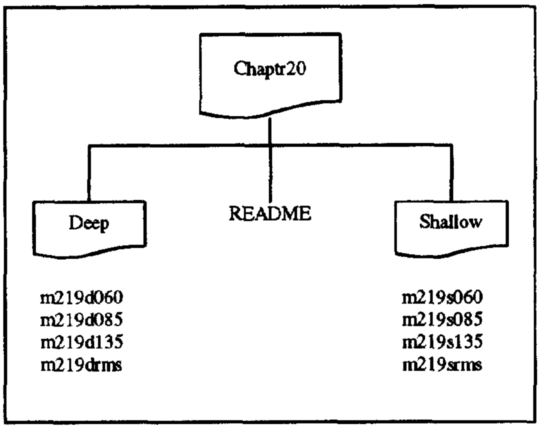


**Figure 3: Layout of electronic data**

| | | | |
|---|---|---|---|
| Sampling frequency (samples/second) | 6000 | Block size | 1024 |
| Block period (seconds) | 0.17067 | Number of averages | 20 |

No windowing was used in this analysis.

| Kulite | X(in) | X/L | Location | Y(in) | |
|---|---|---|---|---|---|
| K1 | -7.0 | | Front | 0.0 | |
| K2 | -4.0 | | plate | 0.0 | |
| K4 | 39.9 | | Rear plate | -3.0 | |
| K7 | 0.0 | | Front wall | 2.5 | |
| K8 | 0.0 | | (Z=-1.0) | -0.5 | |
| | | | 2" cavity | | |
| K9 | 0.0 | | Front wall | 2.5 | |
| K10 | 0.0 | | (Z=-1.0) | -0.5 | |
| | | | 4" cavity | | |
| | | | | Deep | Shallow |
| K20 | 1.0 | 0.05 | | 0.0 | 1.0 |
| K21 | 3.0 | 0.15 | | 0.0 | 1.0 |
| K22 | 5.0 | 0.25 | | 0.0 | 1.0 |
| K23 | 7.0 | 0.35 | | 0.0 | 1.0 |
| K24 | 9.0 | 0.45 | Cavity | 0.0 | 1.0 |
| K25 | 11.0 | 0.55 | ceiling | 0.0 | 1.0 |
| K26 | 13.0 | 0.65 | | 0.0 | 1.0 |
| K27 | 15.0 | 0.75 | | 0.0 | 1.0 |
| K28 | 17.0 | 0.85 | | 0.0 | 1.0 |
| K29 | 19.0 | 0.95 | | 0.0 | 1.0 |
| K37 | Port wall working section | | Tunnel wall | | |

**Table 1 Locations of Kulite transducers, only measurements from those on the cavity ceiling are included in this database.**

| | 2" Depth Cavity | 4"Depth Cavity |
|---|---|---|
| Ceiling | 16 at Y=0", 16 at Y=2" | 16 at Y=2" |
| Front Wall | 8 at Y=2" | 8 at Y=0", 8 at Y=2" |
| Port Side Wall | 20 at Y=-1", Z=-0.25" | 20 at Y=-1", Z=-0.25" |
| Starboard Side Wall | 20 at Y=3", Z=-0.25" | 20 at Y=3", Z=-0.25" |

**Table 2 Static Pressure Measurements Inside Cavity**

| X/L | Deep Cavity | | | Shallow Cavity | | |
|---|---|---|---|---|---|---|
| | M=0.6 | M=0.85 | M=1.35 | M=0.6 | M=0.85 | M=1.35 |
| 0.050 | 0.469 | 1.053 | 2.699 | 0.229 | 0.325 | 0.565 |
| 0.150 | 0.462 | 0.923 | 1.835 | 0.286 | 0.381 | 0.523 |
| 0.250 | 0.486 | 1.083 | 1.590 | 0.488 | 0.555 | 0.707 |
| 0.350 | 0.654 | 1.366 | 2.947 | 0.814 | 0.858 | 0.873 |
| 0.450 | 0.897 | 1.716 | 4.498 | 0.908 | 1.221 | 1.101 |
| 0.550 | 1.046 | 2.079 | 4.742 | 0.721 | 1.285 | 1.372 |
| 0.650 | 1.157 | 2.318 | 4.280 | 0.595 | 1.209 | 1.720 |
| 0.750 | 1.489 | 2.572 | 3.864 | 0.586 | 1.241 | 1.917 |
| 0.850 | 1.929 | 3.490 | 5.724 | 0.799 | 1.604 | 2.263 |
| 0.950 | 2.068 | 4.117 | 8.505 | 1.606 | 3.030 | 3.358 |

**Table 3 RMS Pressure on cavity ceiling.**

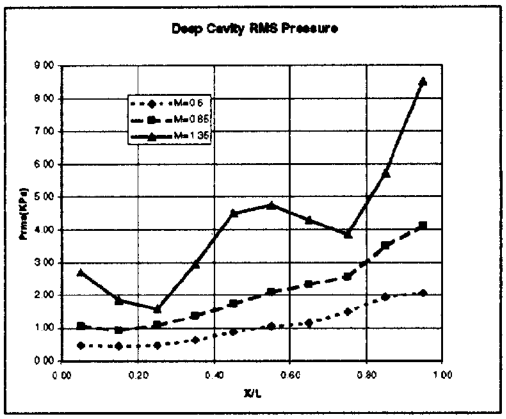


**Figure 4: RMS Pressure distribution along the ceiling of the 'deep' empty cavity.**

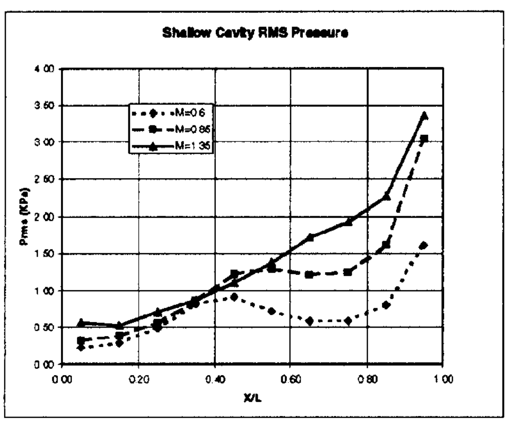


**Figure 5: RMS Pressure distribution along the ceiling of the 'shallow' empty cavity.**


## ACKNOWLEDGEMENTS

Dr. J A Ross of DERA, Bedford, U.K., Mr. Andrea C Hill of ARA Aero. Dept., U.K., and Dr. P E Flood of BAe., Warton, U.K.